



SPACE SHUTTLE PROGRAM
Space Shuttle Projects Office (MSFC)
NASA Marshall Space Flight Center, Huntsville, Alabama



STS-109/ET-112 Flight Readiness Review

External Tank Project



February 14, 2001



Overview

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R. Wetmore / LMSSC-ET/3000

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- **Limited Life Component Status**

- All within required life through scheduled launch date plus 90 days

- **Changes**

- Qualification of New Flex Hose Liner
- Increase LO2 Tank Dome Cap Membrane Thickness
- Revise LH2 PAL Ramp Angular Build Dimension
- Repair Suspect LH2 Line Burst Discs

- **Significant Processing Anomalies**

- LO2 Feedline Foam Concern – To be provided in a separate handout

- **Readiness Statement**



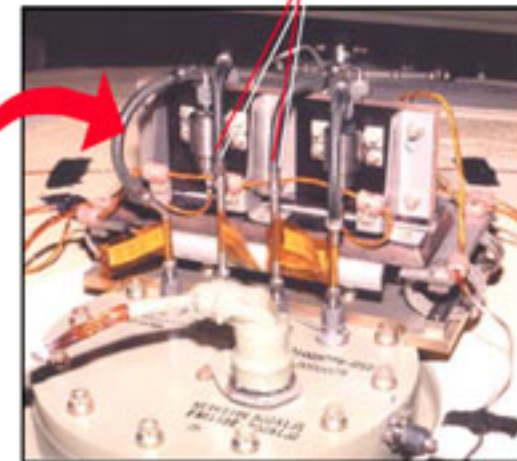
Change Qualification of New Flex Hose Liner

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- **Change**

- Revised manufacturing process used to fabricate convoluted Teflon line in LO2 and LH2 ullage pressure transducer flexible hoses
 - No change in material or dimensions - Only convoluting process changed



Flex Hoses

**Ullage Pressure Transducers
and Flex Hoses
(LH2 installation shown)**

- **Background / Reason for Change**

- Supplier exhausted supply of material and original tooling no longer available
- Hoses are identical in diameter and assembly

- **Basis for Certification**

- No change in acceptance tests (leakage, burst and x-ray)
- Test - Random and Sinusoidal Vibration
 - Strength – No sign of damage from impact or fatigue
 - Leak – No degradation in the pressure decay
 - New hoses did not alter the response of the isolation platforms



Change Increase LO2 Dome Cap Membrane Thickness

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• Change

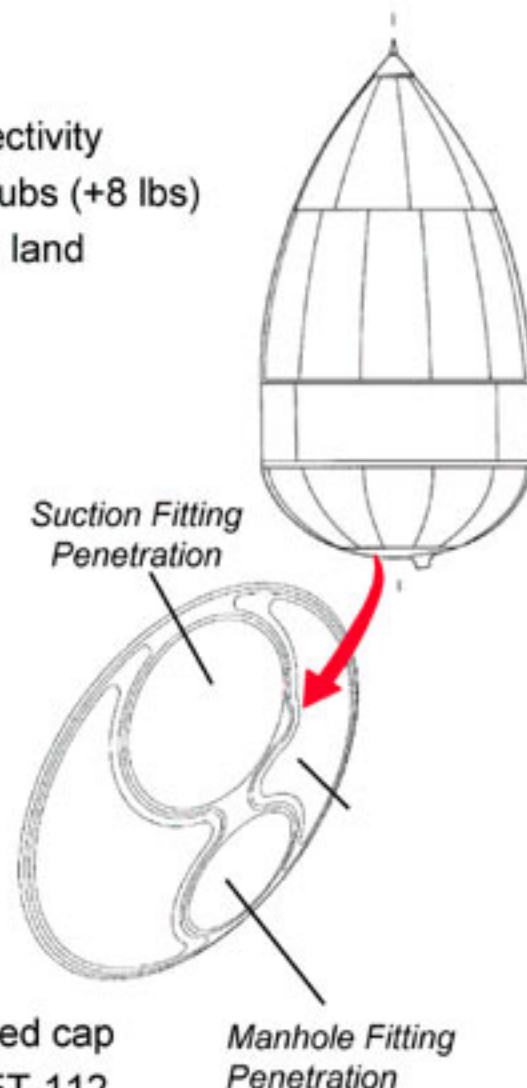
- Reallocated ET-115 LO2 tank dome cap to ET-112 LO2 tank aft dome
 - Reallocation required due to welding issues with dome on earlier effectivity
 - Dome cap acreage membrane thickness increased for ET-115 and subs (+8 lbs)
 - Basic cap design configuration is unchanged (i.e. material, weld land widths, weld land thickness)

• Reason for Change

- SSP requested External Tank certification to higher maximum LO2 tank ullage pressure operating range (expansion of ICD requirements)
 - ICD pressure increase required to allow the Orbiter fleet to use any combination of spare GO2 fixed orifices beginning at ET-115
- Certification to the higher pressures required increases to the dome cap membrane thickness (LO2 proof test pressures, barrel membrane thickness changes to be discussed at STS-112/ET-115 SSV FRR)

• Basis for Certification

- Test - Proof test demonstrates a minimum of 120% of design limit load
- Analysis - Stress analysis shows improved Factors of Safety for redesigned cap
 - Proof and flight pressure requirements are unchanged for STS-109/ET-112



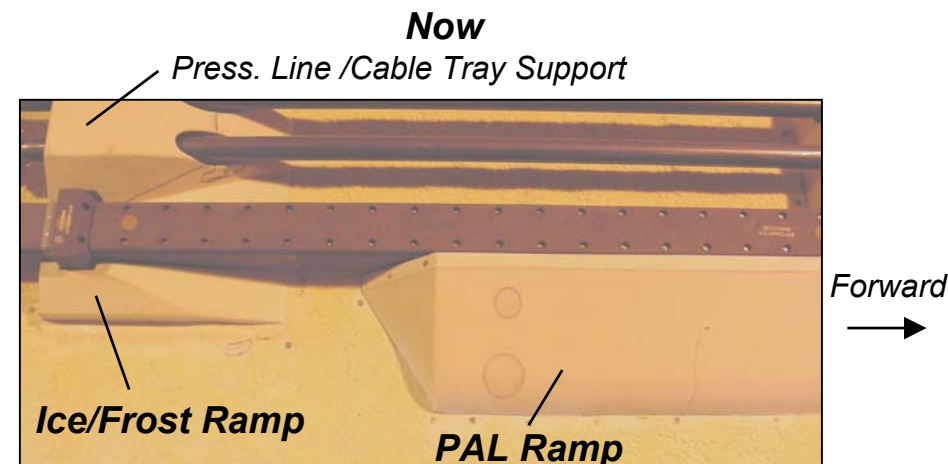
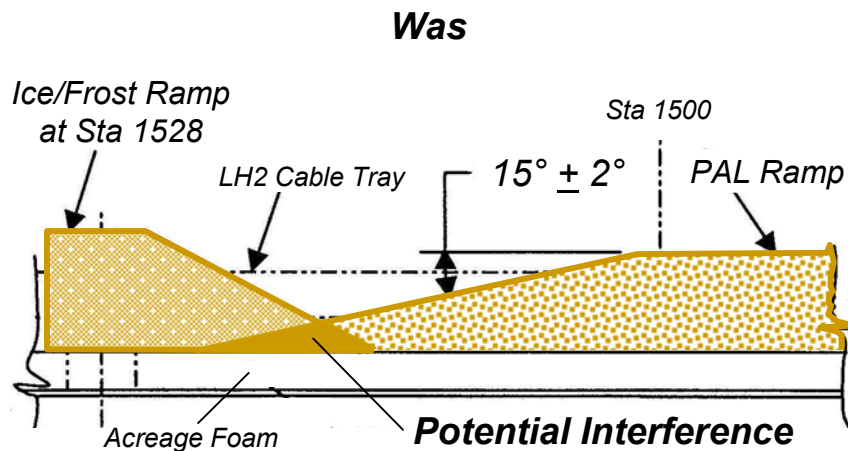


Change Revise LH2 PAL Ramp Angular Build Dimension

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- **Change**
 - Revised ICD / engineering to eliminate potential interference between LH2 PAL (Protuberance Air Load) ramp and the ice/frost ramp
- **Reason for Change**
 - New mold used for ice/frost ramps on LH2 tank ice/frost ramps to reduce acreage foam damage during mold removal
 - Introduction of the new mold identified a potential condition wherein the LH2 PAL ramp if applied to current dimensional requirements could overlay onto the forward surface of the ice/frost ramp at XT1528
 - Potential for interference existed since ET-1
- **Basis for Certification**
 - Analysis - LH2 PAL ramp angular dimension change certified by aero analysis
 - No change to airload methodology





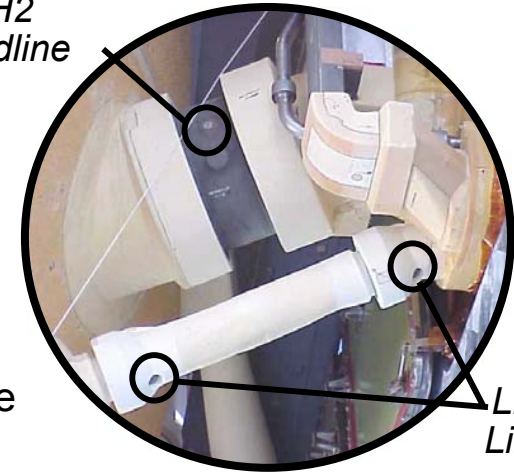
Change Repair Suspect LH2 Line Burst Discs

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- **Change**
 - Repair suspect burst discs using Conathane primer
- **Reason for Change**
 - During a supplier ATP burst discs leaked
 - Leakage at microscopic cracks observed on the part during failure analysis
 - Cracking observed only on small “bumps” in the center of the disc
- **Basis for Certification**
 - Test
 - Method to repair remaining suspect burst discs using Conathane primer developed and validated
 - Repair prevents leakage of burst disc during operations
 - All materials are approved for use on ET flight hardware
 - Testing demonstrated that Conathane repair does not affect the burst pressure of the disc
 - Repair presented to and approved by PRCB 11/19/2001 (S061766)

*LH2
Feedline*

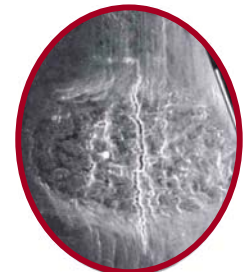


*LH2 Recirc.
Line Bellows*



Burst Disc

Typical Crack
*Approx. 0.008”
in length*



LO2 Feedline Foam Concern

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• Issue

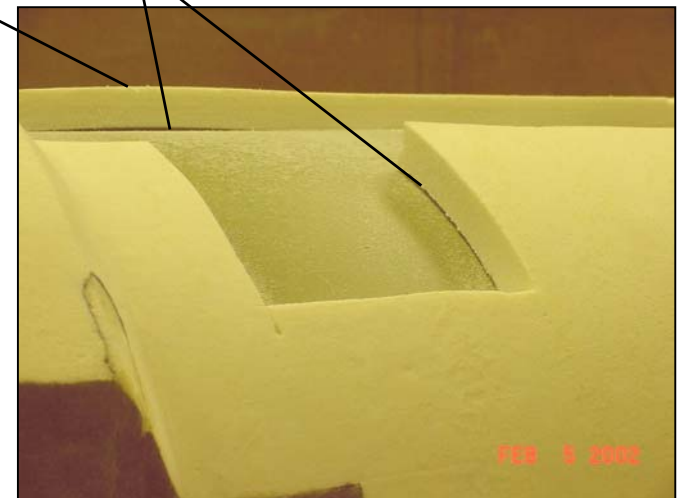
- Suspect foam debond condition exists on one of four straight feedline sections on ET-112/STS-109 (Sta 1623 to Sta 1871)
 - This is the first line section to be sprayed with BX-250 after phase out of SS-1171 (October 2000)

• Background

- During foam closeout of the ET-118 LO2 feedline at MAF, the technician visually noticed a “bump” in the foam approximately 17 in. long and 360° around circumference of the 20 ft long line
- Suspect condition has been isolated to lines with BX-250 foam and to the area at forward end of straight feedline sections near support brackets
 - This area has a thicker initial layer of foam due to the spray start-up process
 - Evidence of distorted foam cells from adverse flow of blowing agent was observed

*Visual “bump”
 in foam*

Debond (after section removed)



Note: Thin foam film remained on substrate indicating no substrate contamination



LO2 Feedline Foam Concern

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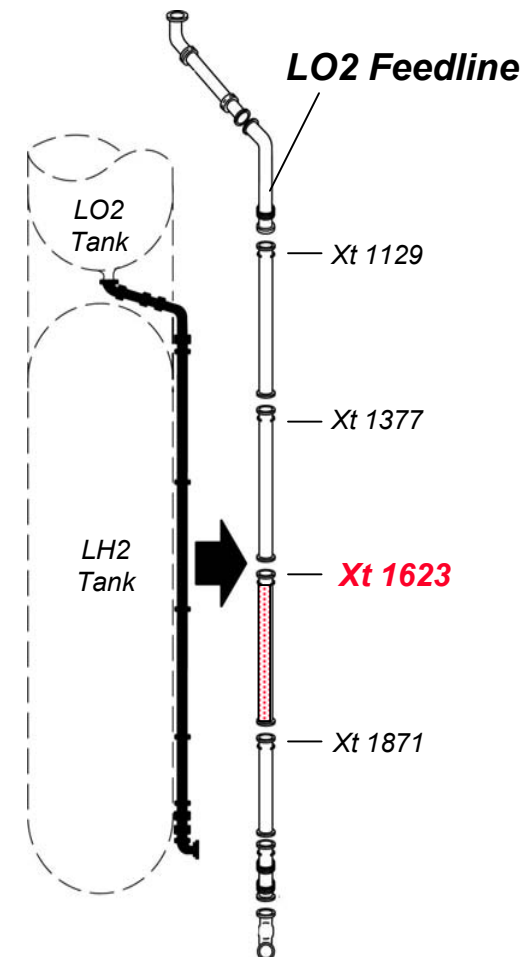
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• Background

- Knit line analysis of removed foam showed that initial layer of foam (applied prior to start of carriage travel) was inordinately thick ($\approx 0.75"$)
 - BX-250 provides better mechanical properties when initial layer of foam is thinner ($0.25"$)
 - SS-1171 produces better mechanical properties when initial layer of foam is thicker ($0.50"$)
- Plug pulls performed on lines with SS-1171 foam confirm that debond condition is isolated to BX-250 sprayed lines
- Problem isolated to foam bond/adhesion only
 - ET-118 foam which essentially had no adhesive bond strength and foam was removed and tested to evaluate foam integrity
 - Foam cohesive strength exceeded design requirements and the values are consistent with typical BX-250 foam
- No concern for other BX-250 foam applications on the ET due to process and location
- Feedline is only semi-automated process



Support
Brackets





LO2 Feedline Foam Concern

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• Discussion

ET-118

- Tests results confirmed that the debond condition is isolated to area near brackets
 - Performed plug pulls on all four line sections
 - All failed pulls were located in area near brackets
 - Machined 4" wide strip down length of line (180° from plug pulls) to inspect bondlines
 - Only debond was in the area near the brackets

STS-110/ET-114

- Performed plug pulls on 3 of 4 straight line sections
 - All plug pull values meet process specification requirements

STS-111/ET-113

- Performed plug pulls on 2 of 4 straight line sections
 - All plug pull values meet process specification requirements

STS-109/ET-112

- Performed six plug pulls on the single BX-250 line section installed
 - Four of six plug pulls exceeded the process specification requirement (35 psi)
 - The lowest plug pull exhibited a value of 12.6 psi - Foam was not debonded



LO2 Feedline Foam Concern

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• Rationale for Flight

- Investigations have shown the area of bond weakness is limited to local regions
 - Cut-ups, plug pulls, tactile and visual examination of foam on 13 feedlines have characterized the bondline conditions
 - Only one of thirteen lines showed a debond (ET-118)
 - The width of the band with weak bond strength (< 35 psi plug pulls) is 4.75"
- Analysis considering pressure entrapped in foam and flight environment (vacuum, heating, LO2 in line, vibration and air loading) shows large factors of safety (>> 2.0)
 - Driving environments are the foam cell pressure, cryogenic temperature and the vacuum of space
 - Vibration and air loading are insignificant contributors
 - Assumes that this region unbonded
 - Zero psi bond strength vs a measured minimum of 12.6 psi
 - Cell pressure at bondline is reduced from 14.7 psi to 4.5 psi because of LO2 temperature of line
 - External pressure exceeds 4.5 psi through 57 sec of flight
 - Foam ability to carry pressure as hoop tension is conservatively neglected
 - Volume change from foam deflection results in reduced pressure
 - Shows the ability of foam to redistribute load to adjacent foam
- Analysis of a debond 2 x 4.75" area of reduced bond strength results in a >> 2.0 FS



LO2 Feedline Foam Concern

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- **Conclusions**

- LO2 feedline foam is acceptable for flight
- Large Factor of Safety against foam loss



Readiness Statement

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**The External Tank, ET-112, is certified and
ready for STS-109 flight pending
completion/closure of open and planned work**